SWGDE Technical Notes on FFmpeg

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SWGDE Technical Notes on FFmpeg

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1. **Purpose**

This document provides a general awareness of FFmpeg, its functions, basic use, and common uses as it pertains to digital forensics. FFmpeg (Fast Forward mpeg) is an open source, cross-platform framework that uses command line to play, convert, and stream audio and video. This framework is used by multiple applications for forensic and commercial purposes.

2. **Scope**

The intended audience is forensic video analysts/examiners trained and experienced in the examination of video seeking direction and familiarization in the use of FFmpeg’s open source suite. It focuses on basic commands and principles, as well as some commands commonly used in video analysis. The nature of FFmpeg is that it is constantly being collaborated and expanded. As more commands prove useful, they can be added to this document.

3. **Limitations**

This document was prepared with the resources available at the time of publication. As with all technology, FFmpeg is a constantly evolving environment with frequent implementation of new features and innovations. The specific configuration of any particular installation will vary widely and may not conform to the standards cited here. This document is not intended for use as a step-by-step guide for conducting a thorough forensic investigation, nor is it legal advice. While FFmpeg will process many video codecs, it may not work in every instance. This is not a best practices guideline and should not replace proper training and tool validation.

4. **FFmpeg Tools**

4.1 **FFprobe**

A multimedia tool that provides metadata about digital multimedia including but not limited to duration, frame rate, frame size, aspect ratio, codec, streams (video, audio, and data), etc.

4.2 **FFplay**

A media player that utilizes the FFmpeg framework to display multimedia files. While not all encompassing, it will play proprietary and open source media files.

4.3 **FFmpeg**

A command line tool to convert multimedia file formats as well as various properties within the file such as codecs, container, frame rate, aspect ratio, and still images.
5. **FFmpeg Installation**

### 5.1 Windows Installation

- Download the latest STATIC version from ffmpeg.zeranoe.com/builds/
- Use 7zip compatible software to "extract all" from the downloaded file; it will put everything in one folder
- On the C drive, create a folder named "ffmpeg"
- Copy everything from the extracted folder into the "ffmpeg" folder on the C drive
- Click on "Environment Variables"
- Under "User Variables for User", click "New"
- Under "Variable Name" type the word "Path"
- Under "Variable Value" type "c:\ffmpeg\bin"
- Click "Ok"

### 5.2 Mac Installation

Homebrew is a command-line package manager that will automatically install and attach dependencies. Using Homebrew requires both an internet connection and installation of Homebrew first. The steps below will address installation of Homebrew and FFmpeg.

- **In Terminal, type:**
  ```bash
  /usr/bin/ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/master/install)"
  ```
- **Follow the on-screen instructions; this will take a few minutes while it's installing the necessary developer tools for OS X**
- **After successful installation run:** `brew install ffmpeg` to get the latest released version and library dependencies
- **To see additional installation options, run:** `brew info ffmpeg`. These may include:
  ```bash
  brew install ffmpeg
  ```
  ```bash
  --with-fdk-aac
  --with-ffplay
  --with-freetype
  --with-libass
  --with-libvpx
  --with-opus
  --with-x265
  ```
- **To update ffmpeg, run:** `brew update && brew upgrade ffmpeg`

Note: For these instructions and additional options visit: https://trac.ffmpeg.org/wiki/CompilationGuide/MacOSX
6. **FFmpeg Informational Commands**

6.1 **Help**

- `FFprobe -h`
- `FFplay -h`
- `FFmpeg -h`

6.2 **Show License**

   (lower-case L)

- `FFprobe -l`
- `FFplay -l`
- `FFmpeg -l`

6.3 **Installed Codecs**

- `FFprobe --codecs`
- `FFplay --codecs`
- `FFmpeg --codecs`

---

7. **Basic Command Entry Format**

In this document, all input files will be referred to as “input.dvr”.

7.1 **FFprobe**

```
FFprobe input.dvr
```

**FFprobe**

Starts the command

**input.dvr**

Gives the location of the file

**Enter**

Runs the command

*Shortcut:* drag the file into the FFmpeg window to populate the path address into the command line.
7.1.1 Sample result from FFprobe:

Duration: 00:00:43.46, start: 1.03367, bitrate: 23760 kb/s
Stream #0:0[0x1011]: Video: h264, yuv420p(top first), 1920x1080 [SAR 1:1 DAR 16:9], 2500 kb/s, 29.97 fps, 59.94 tbr, 90k tbn, 59.94 tbc
Stream #0:1[0x1100]: Audio: ac3 (AC-3 / 0x3320D4341), 48000 Hz, stereo, fltp, 256 kb/s
Stream #0:2[0x1200]: Subtitle: hdmv_pgs_subtitle ([144][0][0][0] / 0x0090), 1920x1080

7.1.2 Explanation of results:

Duration
Shows the duration of the file: 00:00:43.46

Video
Shows the video codec used in the file. This file is identified as using h264

1920x1080
Shows the pixel dimensions of the video

29.97 fps
Shows the frames per second (fps)
FFprobe can be used to provide generic metadata information about the file or as complex as byte level analysis of individual frames, audio streams and data streams.

7.2 FFplay

FFplay

Starts the command

input.dvr

Gives the location and name of the video to be played

Enter

Runs the command

If video does not play, use the metadata provided by FFprobe to instruct FFplay to force the format of the video file. Example below is forcing h264 format.

FFplay

Starts the command

-f h264

Forces the format to h264

input.dvr

Gives the location and name of the file

Video window opens and begins playback.
Other commonly used formats include but are not limited to:

- H264
- M4V
- MJPEG
- MPEG2
- H263

For a list of other formats available in FFplay type:

**FFplay -formats**

FFplay controls for operation of playback window:

- Pause/Play: P key or Spacebar
- Scrub forward: On the video window, click and drag mouse to the right
- Scrub backward: On the video window, click and drag mouse to the left
- Frame forward: S key
- Display audio waveform: W key
- Toggle view of waveform or spectral frequency display: W key
- Full screen: F key
- To quit or close window: Q key or ESC key
- To mute: M key
- Set Volume: Press and hold 9 key to lower volume or 0 key to increase volume
- Decrease/Increase volume: / and * respectively
- Cycle audio streams: A
- Cycle video streams: V
- Cycle subtitle streams: T
- Cycle program: C
- Seek backward/forward 10 seconds: Left/Right keys
- Seek backward/forward 1 minute: Down/Up keys
- Seek backward/forward 10 minutes: Page Down/Page Up
7.3 FFmpeg

This is the basic command structure for FFmpeg; all other commands will follow this structure:

[Call Program][input Arguments]-i[Input File][Output Arguments][Output file]

For example, this command plays the inputted file at 10 frames per second, and transcodes it to an uncompressed AVI.

```
ffmpeg -r 10 -i input.dvr -c:v rawvideo -f avi output.avi
```

FFmpeg
- Starts the command.

-r 10
- Tells FFmpeg the video input should be played at 10 frames per second.

-i input.dvr
- Path and name of input file

-c:v rawvideo
- Tells FFmpeg to transcode the video stream to an uncompressed video format

-f avi
- Tells FFmpeg to wrap the video in an AVI container with necessary header information

Output.avi
- Path and name of output file
7.3.1 To change the file container without transcoding the stream information:

```
ffmpeg -i input.dvr -c:v copy -f avi output.avi
```

**FFmpeg**

Starts the command

- `i input.dvr`
  Path and name of input file

- `c:v copy`
  Tells FFmpeg to copy the original video stream data

- `f avi`
  Tells FFmpeg to wrap the video in an AVI container with necessary header information

**output.avi**

Path and name of output file

7.3.2 Output uncompressed AVI

```
ffmpeg -i input.dvr -c:v rawvideo -f avi output.avi
```

**FFmpeg**

Starts the command

- `i input.dvr`
  Path and name of input file

- `c:v rawvideo`
  Tells FFmpeg to transcode the video stream to an uncompressed video format

- `f avi`
  Tells FFmpeg to wrap the video in an AVI container with necessary header information

**output.avi**

Path and name of output file
7.3.3 Force FFmpeg to read file with a specific codec and change the file container

```
ffmpeg -f h264 -i input.dvr -c:v copy -f avi output.avi
```

**FFmpeg**

Starts the command

*f h264*

Tells FFmpeg the video stream should be forced to play as h264, regardless of file data. Other common dvr codecs are mjpecg, h263, and m4v

*i input.dvr*

Path and name of input file

*c:v copy*

Tells FFmpeg to copy the inputted video codec

*f avi*

Tells FFmpeg to wrap the video in an AVI container with necessary header information

**Output.avi**

Path and name of output file

7.3.4 Change the framerate and the file container

```
ffmpeg -r 10 -i input.dvr -c:v copy -f avi output.avi
```

**FFmpeg**

Starts the command

*r 10*

Tells FFmpeg the video input should be played at 10 frames per second. This can come after the input file, but that is not forensically recommended, as that tells FFmpeg to play the output file at the listed frame rate, potentially adding frames to pad.

*i input.dvr*

Path and name of input file

*c:v copy*

Tells FFmpeg to copy the inputted video codec

*f avi*

Tells FFmpeg to wrap the video in an AVI container with necessary header information

**Output.avi**

Path and name of output file
7.3.5 Output frames from video

7.3.5.1 Output all video file I-frames to uncompressed sequential still images

```bash
ffmpeg -i input.dvr -vsync drop -vf select='eq(pict_type,I)' -f image2 -pix_fmt rgb24 foldername\frame%05d.tiff
```

**ffmpeg**

Starts the command

- `i input.dvr`
  Path and name of input file

- `vsync drop`
  Video sync option which tells FFmpeg to disregard timestamp information

- `vf select='eq(pict_type,I)'`
  Tells FFmpeg to select frames based on a picture type, in this case I-frames. Other options include P for P-frames, and B for B-frames. Can be comma delimited to combine

- `f image2`
  Tells FFmpeg to encode the selected image type(s) into an image sequence

- `pix_fmt rgb24`
  Tells FFmpeg to format the images as 24 bit RGB images

- `foldername\frame%05d.tiff`
  Specifies an output folder and a title for the images numbered in a 5 digit sequence as TIFF files.

7.3.5.2 Output individual frames from video stream

```bash
ffmpeg -i input.[extension] -an -f image2 output_%05d.[extension]
```

**ffmpeg**

Starts the command

- `i input.[extension]`
  Path and name of input file

- `an`
  Tells FFmpeg to exclude any existing audio tracks in the file

- `f image2`
  Tells FFmpeg to extract still images for each frame of video

- `output %05d.[extension]`
  Path and name of output file, the extension will force the still image extraction to a desired still image format, e.g., .jpg, .tiff, or .png.
7.3.6 Export a portion of the video as an uncompressed avi

```bash
ffmpeg -ss 0:00:10.000 -i input.dvr -t 0:00:05.000 -c:v rawvideo -f avi output.avi
```

**FFmpeg**

- Starts the command
- **-ss 0:00:10.000**
  - Tells FFmpeg to seek to a time in the video using the format hours:minutes:seconds.milliseconds
- **-i input.dvr**
  - Path and name of input file
- **-t 0:00:05.000**
  - Tells FFmpeg to play for a specific amount of time. Format is the same as -ss
- **-c:v rawvideo**
  - Tells FFmpeg to transcode the video stream to an uncompressed video format
- **-f avi**
  - Tells FFmpeg to wrap the video in an AVI container with necessary header information
- **output.avi**
  - Path and name of output file

7.3.7 Concatenate common files into an avi

There are some caveats with concatenation. Before concatenating, all videos should be from the same source, with the same frame rate and the same codec. The basic command for this is:

```bash
ffmpeg -i "concat:input1.dvr|input2.dvr|input3.dvr" -c copy output.dvr
```

**FFmpeg**

- Starts the command
- **-i "concat:input1.dvr|input2.dvr|input3.dvr"**
  - Tells FFmpeg to combine the files in the order they are entered. FFmpeg will start with the first file in the list, and continue until the last file is completed.
- **-c copy**
  - Tells FFmpeg to copy the inputted codec. This will include all streams within the file (e.g., video, audio, timecode)
- **output.dvr**
  - Path and name of output file
For more efficient concatenation of multiple files, the input can be done from a list.txt file. The text in the list needs to be structured as follows:

```plaintext
file 'input1.dvr'
file 'input2.dvr'
file 'input3.dvr'
```

This can be created manually, or as a loop. For example, in Windows command-line, this command will create a list.txt file for all similar files in a folder.

```plaintext
(for %i in (*.dvr) do @echo file '%i') > list.txt
```

Once a list.txt file has been created, use the following command to combine all listed files into one file.

```plaintext
ffmpeg -f concat -i list.txt -c copy -f avi output.dvr
```

**FFmpeg**
- Starts the command
- `-f concat` Tells FFmpeg to concatenate all the files in the input
- `-i list.txt` Is the path and name of the list.txt file. FFmpeg will start with the first file in the list and continue until the last file is completed.
- `-c copy` Tells FFmpeg to copy the inputted codec. This will include all streams within the file (e.g., video, audio, timecode)
- `-f avi` Tells FFmpeg to wrap the video in an AVI container with necessary header information

**Output.avi**
- Path and name of output file

One note from FFmpeg documentation: If using MP4 files, these could be losslessly concatenated by first transcoding them to mpeg transport streams. With h.264 video and AAC audio, the following commands can be used:

```plaintext
ffmpeg -i input1.mp4 -c copy -bsf:v h264_mp4toannexb -f mpegts temp1.ts
ffmpeg -i input2.mp4 -c copy -bsf:v h264_mp4toannexb -f mpegts temp2.ts
ffmpeg -i "concat:temp1.ts|temp2.ts" -c copy -bsf:a aac_adtstoasc output.mp4
```
7.4 Commonly Used FFmpeg Audio Commands

7.4.1 Output Audio Only from a File

```
ffmpeg -i input.dvr -c:a copy -vn -f wav output.wav
```

**ffmpeg**

Starts the command

- **-i input.dvr**
  
  Path and name of input file

- **-c:a copy**
  
  Tells FFmpeg to copy the inputted audio codec

- **-vn**
  
  Tells FFmpeg to ignore and remove any video stream present

- **-f wav**
  
  Tells FFmpeg to wrap the audio in a wav container with necessary header information

- **output.wav**
  
  Path and name of output file

7.4.2 Output uncompressed AVI with lossless audio

```
ffmpeg -i input.dvr -c:a pcm_s16le -ar 44100 -c:v rawvideo -f avi output.avi
```

**ffmpeg**

Starts the command

- **-i input.dvr**
  
  Path and name of input file

- **-c:a pcm_s16le**
  
  Tells FFmpeg to transcode the audio stream to an uncompressed 16-bit audio format

- **-ar 44100**
  
  Tells FFmpeg to sample the transcoded audio as a Sample Rate of 44.1kHz

- **-c:v rawvideo**
  
  Tells FFmpeg to transcode the video stream to an uncompressed video format

- **-f avi**
  
  Tells FFmpeg to wrap the video in an AVI container with necessary header information

- **output.avi**
  
  Path and name of output file
8. Video Analysis Commands

8.1 Create an MP4 Video with a Visual Display of Macroblock Types
(Note - Decoding of macroblock types is MPEG-specific)

```
ffmpeg -debug vis_mb_type -i input.dvr output.mp4
```

FFmpeg

Starts the command

- `debug vis_mb_type`
  Tells FFmpeg to visualize block types

- `i input.dvr`
  Path and name of input file

- `output.mp4`
  Path and name of output file (MP4 format)

8.2 Macroblock Analysis Visual Display Reference Chart
(Colors below are displayed in the order that they are parsed)

<table>
<thead>
<tr>
<th>Color</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New data</td>
</tr>
<tr>
<td></td>
<td>New data</td>
</tr>
<tr>
<td></td>
<td>16x16 Skip macroblock (P or B slices)</td>
</tr>
<tr>
<td></td>
<td>Reference to past (List 0, P or B slices)</td>
</tr>
<tr>
<td></td>
<td>Reference to future (List 1, B slices)</td>
</tr>
<tr>
<td></td>
<td>Reference to past and future (List 1 &amp; 2, B slices)</td>
</tr>
<tr>
<td></td>
<td>Generally indicates no change to the macroblock</td>
</tr>
</tbody>
</table>

8.3 Video Frame Information Report

This report shows time and display information for each frame in a video.

```
ffprobe -show_frames -print_format xml input.dvr > output.xml
```

FFprobe

Starts the command

- `show_frames`
  Shows information for each frame

- `print_format xml`
  Tells FFprobe to send frame information into an XML file

- `input.dvr>output.xml`
  Gives the name of the input file and path, and sends it to the listed output.xml name and path
8.4 Frame-level MD5

This procedure provides a methodology for verifying lossless changing of a codec from one container to another container using ffmpeg’s framemd5 command, which currently only supports the md5 algorithm. First, generate md5 values for every frame in a video file. Then, change the container of the video file into a new container (e.g., AVI, MOV). Then create md5 values for the new video file. Finally, compare the two sets of framemd5 values to prove that the video/audio information has not changed during the container changing process. The following sections provide instructions for this process.

8.4.1 Generate md5 values for every frame in a video file

First use ffmpeg to create a text file that includes an md5 value for each frame in the first file that you want to compare.

```
ffmpeg -i input.dvr -f framemd5 file1.md5.txt
```

**FFMPEG**
- Starts the command
- `-i input.dvr`
  - Path and name of the input file
- `-f framemd5`
  - Instructs ffmpeg to create md5 hash values for each frame of video data
- `file1.md5.txt`
  - Instructs ffmpeg to output the result of the framemd5 to a particular text file

8.4.2 Create md5 values for the new video file

Using a second file that you want to compare to the first file, create a text file that includes an md5 value for each frame in the second file.

```
ffmpeg -i input.dvr -f framemd5 file2.md5.txt
```

**FFMPEG**
- Starts the command
- `-i file2`
  - Path and name of input file
- `-f framemd5`
  - Instructs ffmpeg to create md5 hash values for each frame of video data
- `file2.md5.txt`
  - Instructs ffmpeg to output the result of the framemd5 to a particular text file
8.4.3 Compare the two sets of framemd5 values

In order to compare the two files, use a comparison technique to compare the text of the two framemd5 files to look for any differences in them. If there are no differences, then you have an exact match in frame count, frame size, and byte order per frame.

```
FC file1.md5.txt file2.md5.txt > result.txt
```

**FC**

FC is a Windows operating system command to compare the textual content of two specified files

**file1.md5.txt**

Specifies the first input file

**file2.md5.txt**

Specifies the second input file

**> result.txt**

Instructs FC to output the result of the comparison to a particular text file
### SWGDE Technical Notes on FFmpeg

#### History

<table>
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<tr>
<th>Revision</th>
<th>Issue Date</th>
<th>Section</th>
<th>History</th>
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<tr>
<td>1.0 DRAFT</td>
<td>2016-09-15</td>
<td>All</td>
<td>Initial drafted and SWGDE voted to release as a Draft for Public Comment.</td>
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<td>2017-01-12</td>
<td>7.3, 7.4, 8.4</td>
<td>Added Section 7.3.5.2 Output individual frames from video stream. Added Section 7.4 Commonly Used FFmpeg Audio Commands. Added 8.4 Frame-level MD5. SWGDE voted to re-release as a Draft for Public Comment.</td>
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<td>Formatting</td>
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<tr>
<td>1.0 DRAFT</td>
<td>2017-05-30</td>
<td>All images</td>
<td>Updated all images with new, original images. Re-released as a Draft for Public Comment.</td>
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<tr>
<td>1.0</td>
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<td>None</td>
<td>SWGDE voted to publish as Approved, pending completion of 60-day draft period if no additional comments are received.</td>
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<tr>
<td>1.0</td>
<td>2017-07-31</td>
<td>Formatting</td>
<td>Formatting and technical edit performed and published as Approved version 1.0.</td>
</tr>
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